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MULTIFOCAL LENS DESIGNS WITH INTERMEDIATE OPTICAL POWERS
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(57) Claim

1. A multifocus, concentric annular ring lens comprising:

a. said lens having a front surface and an opposite back surface, wherein one of the front and back surfaces defines a central area comprising a circular disc having a spherical surface corresponding to a basic prescription Rx spherical distance optical power;

b. a plurality of annular rings surrounding the central area and having alternating spherical near optical powers and spherical distance optical powers; and

c. at least one intermediate optical power annular ring, located in the outer region of the lens optic zone, having an intermediate optical power, intermediate to the distance optical power and the near optical power, to provide visual acuity at intermediate distances.

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COMPLETE SPECIFICATION

FOR A STANDARD PATENT

ORIGINAL

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Invention Title: MULTIFOCAL LENS DESIGNS WITH INTERMEDIATE
OPTICAL POWERS

The following statement is a full description of this invention, including the best method of performing it known to us.

1 MULTIFOCAL LENS DESIGNS
 WITH INTERMEDIATE OPTICAL POWERS

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

The present invention relates generally to multifocal lens designs with intermediate optical powers, and more particularly pertains to multifocal lens designs with intermediate optical powers which provide for visual acuity at intermediate distances by adding one or more intermediate optical power annular rings to a multifocal concentric annular ring lens.

2. Discussion of the Prior Art

The present invention pertains to ophthalmic lenses, and in particular to contact lenses such as soft hydrogel contact lenses, and intracocular lenses, having more than one optical power or focal length.

It is well known that as an individual ages, the eye is less able to accommodate, i.e., bend the natural lens in the eye in order to focus on objects that are relatively near to the observer. This condition is referred to as presbyopia, and presbyopes have in the past relied upon spectacles or other lenses having a number of different regions with different optical powers to which the wearer can shift his vision in order to find the appropriate optical power for the object or objects upon which the observer wishes to focus.

With spectacles the process involves shifting one's field of vision from typically an upper lens portion far power to a lower lens portion near power.

1 With soft or hydrogel contact lenses, however, this
approach has been less than satisfactory. The contact
lens, working in conjunction with the natural lens,
forms an image on the retina of the eye by focusing
5 light incident on each part of the cornea from different
field angles onto each part of the retina in order to
form an image. This is demonstrated by the fact that as
the pupil contracts in response to brighter light, the
image on the retina does not shrink, but rather, light
10 comes through a smaller area of the lens to form the
entire image.

Similarly, for a person that has had the
natural lens of the eye removed because of a cataract
condition and an intraocular lens inserted as a
15 replacement, the ability to adjust the lens
(accommodate) to the distance of the object being viewed
is totally absent. In this case, the lens provided is
usually set at a single infinite distance focal power,
and spectacles are worn to provide the additional
20 positive optical power needed for in-focus closer
vision. For such a patient, a functional multifocal
lens would be particularly useful.

It is also known in the art that under certain
circumstances the brain can discriminate between
25 separate competing images by accepting an in-focus image
and rejecting an out-of-focus image.

One example of this type of lens used for the
correction of presbyopia by providing simultaneous near
and far vision is described in U.S. Patent 4,923,296 to
30 Erickson. This patent discloses a lens system which
comprises a pair of contact lenses, each having equal

areas of near and distant optical power, with the lens for one eye having a near upper half and a distant lower half and the lens for the other eye having a distant upper half and near lower half. Together they provide at least partial clear images in both eyes, and through suppression by the brain of the blurred images, allow alignment of the clear images to produce an in-focus image.

U.S. Patent 4,890,913 to de Carle describes a bifocal contact lens comprising a number of annular zones having different optical powers. The object in the design of this lens is to maintain, at all times regardless of pupil diameter, an approximately equal division between near and distant powers, which requires between six and twelve total zones on the lens.

Another attempt at providing a bifocal contact lens is described in U.S. Patent 4,704,016 to de Carle. Again, this lens attempts to maintain, at all times regardless of pupil diameter, an approximately equal division between near and distant powers.

Patent application Serial No. 07/988,088 (attorney docket VTN 56), entitled PUPIL TUNED MULTIFOCA~~L~~ OPTHALMIC LENS, discloses a multifocal concentric ophthalmic lens for presbyopic patients constructed with three general annular lens portions in a multifocal design. A central circular portion of the lens has only the patient's distance corrective power, and is surrounded by a first inner annular portion, which can consist of multiple annular rings having an inner radial portion which enhances the patient's near focal power encircled by radial portions of

1 substantially equal cumulative amounts of distance and
near optical power focal correction for the patient.
This is surrounded by a second outer annular portion,
which can also consist on one or more annular rings
5 having additional distance focal power near the
periphery of the optical surface area of the ophthalmic
lens. Each annular ring has either a near or distance
optical power and works in combination with other lens
portions to yield the desired focal ratio in that
10 portion of the lens.

Trifocal spectacles are also well known in the
prior art in which an upper spectacle lens portion has a
prescription for far vision, a lower spectacle lens
portion has a prescription for near vision, and an
15 intermediate spectacle lens portion, positioned between
the upper and lower lens portions, has a prescription
for intermediate vision. Moreover, blended trifocal and
multifocal spectacles are also known in which an upper
lens portion has a prescription for far vision, and a
20 lower lens portion has a prescription for near vision,
and an intermediate lens portion has a blended
prescription which changes gradually from the optical
power for the upper portion to the optical power for the
lower lens portion.

25 However, these concepts are not readily
extendible to contact or intraocular lenses, as a wearer
cannot shift his vision through different upper and
lower areas of a contact or intraocular lens. The only
change that the eye makes with respect to a contact or
30 intraocular lens is an involuntary control over the

1 diameter of the pupil, which decreases in bright light
and increases in dim light.

SUMMARY OF THE INVENTION

5 It is an object, therefore, of the present
invention to provide an ophthalmic lens for a presbyope
that yields improved visual acuity in general, and in
particular, matches the focal requirements of
intermediate distance conditions.

10 The present invention provides a contact or
intraocular lens which matches the distribution of near,
intermediate and distance focal vision corrections to
the type of human activity typically undertaken in
various illumination conditions. The present invention
also matches the particular dimensions of a contact lens
15 to suit the size of the pupil of the wearer as a
function of illumination intensity. The ophthalmic lens
is designed to provide predominantly distance correction
under high illumination, nearly evenly divided distance
and near corrections under moderate illumination, and
20 provide intermediate vision correction under low to
moderate illumination levels. The lens is also
specifically designed to match the wearer's pupil size
as a function of illumination level, and in preferred
embodiments by also applying pupil size parameters as a
25 function of the age of the wearer.

Accordingly, it is a primary object of the
present invention to provide multifocal lens designs
with intermediate powers which address the problem of
intermediate optical distance vision by adding one or
30 more intermediate optical power annular rings to a
multifocal concentric annular ring lens.

1 A preferred intermediate optical power is
substantially 50% of the add difference between the
distance power and the near power, but could be chosen
to be any optical power between the distance and near
5 optical powers.

In accordance with the teachings herein, the
present invention provides a multifocus, concentric
annular ring lens wherein one of the front and rear
surfaces of the lens defines a central area comprising a
10 circular disc having a spherical surface corresponding
to a basic prescription Rx spherical distance optical
power. A plurality of annular rings surround the
central area and have alternating spherical near optical
powers and spherical distance optical powers, and at
15 least one intermediate optical power annular ring. The
intermediate optical power annular ring may be located
in the outer region of the lens optic zone, and its
optical power is intermediate to the distance and near
optical powers, to provide visual acuity at intermediate
20 distances.

In greater detail, the intermediate optical
power annular ring or rings can be placed in the outer
radial portion of the optic zone, where it can be an
annular ring in that portion, or it may consist of the
25 entire outer radial portion, or it can be placed in the
middle radial portion, where it is preferably placed in
the outer edge thereof, or it may be placed anywhere in
that portion. The lens can be a contact lens to be worn
on the cornea of the eye, such as a soft hydrogel
30 contact lens, or can be an intraocular lens. The
central area and the plurality of annular rings are

1 preferably formed on the back surface of a contact lens
to minimize flare and glare problems. Moreover, the
widths of the individual annular rings can be different
to generate a power profile which varies to generate
5 different ratios of distance optical power to
intermediate and near optical power.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing objects and advantages of the
present invention for multifocal lens designs with
10 intermediate optical powers may be more readily
understood by one skilled in the art with reference
being had to the following detailed description of
several preferred embodiments thereof, taken in
conjunction with the accompanying drawings wherein like
15 elements are designated by identical reference numerals
throughout the several views, and in which:

Figure 1 is a plan view of a first embodiment
of a multifocal lens design having an intermediate
optical power wherein an intermediate optical power
20 annular ring is the outermost annular ring in the middle
portion of the optical zone of the lens;

Figure 2 is a plan view of a second embodiment
of a multifocal lens design having an intermediate
optical power wherein an intermediate optical power
25 annular ring is the outermost annular ring in the
optical zone of the lens.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring to the drawings in detail, Figure 1
illustrates a preferred type of embodiment of a lens 10
30 designed pursuant to the teachings of the present
invention wherein a central area 12 is a circular disc

1 containing the basic prescribed Rx spherical distance
power, and is surrounded by a plurality of alternating
spherical near power and spherical distance power
annular rings 14, 16, 18 and 20. In the first
5 embodiment of Figure 1, an intermediate optical power
annular ring 22, having an optical power intermediate to
the distance and near optical powers, is added as the
second outermost annular ring. The intermediate optical
power annular ring 22 is encompassed by an outermost
10 distance optical power annular ring 24.

A preferred intermediate optical power is 50%
of the difference between the distance and near optical
powers, but could be chosen to be any optical power
between the distance and near optical powers. A
15 preferred position for the intermediate optical power
annular ring is in the outer region of the lens optic
zone 26, preferably the second outermost annular ring 22
from the outer edge of the lens optic zone 26. The
totality of the area encompassed by the outer
20 circumference of the outermost ring 24 defines the optic
zone 26 of the lens 10, which includes the areas of 12,
14, 16, 18, 20, 22 and 24. The optic zone 26 is
surrounded by a peripheral zone 28, which is a
nonoptical area of the lens, which is beveled at 30 to
25 the outer circumference 32 of the lens.

In greater detail, in one exemplary designed
embodiment, the center disc 12 and the annular rings 16,
20 and 24 have a distance radius of 8.4 mm, while
annular rings 14 and 18 have a near radius of 8.69443
30 mm, annular ring 22 has an intermediate curve radius of
8.3803 mm, and the peripheral curve radius is 9.832 mm.

1 The center toric disc 12 has a diameter of
2.15 mm, annular ring 14 has a diameter of 3.30 mm,
annular ring 16 has a diameter of 3.60 mm, annular ring
18 has a diameter of 4.36 mm, annular ring 20 has a
5 diameter of 4.80 mm, annular ring 22 has diameter of
5.35 mm, annular ring 24 has a diameter of 8.00 mm, the
lenticular annular area 28 has a diameter of 13.0 mm to
the start of beveled area 28, and the outer
circumference of the lens has a diameter of 14.0 mm.

10 Figure 2 is a plan view of a second embodiment
of a multifocal lens design having an intermediate
optical power wherein the intermediate optical power
annular ring 44 is the outermost annular ring 44 in the
optical zone 46 of the lens. Similar to the first
15 embodiment, a central area 32 is a circular disc
containing the basic prescribed Rx spherical distance
power, and is surrounded by a plurality of alternating
spherical near power and spherical distance power
annular rings 34, 36, 38, 40 and 42. The intermediate
20 optical power annular ring is the outermost annular ring
44 within the lens optic zone 46. The combined areas of
the center spherical disc 32 and the surrounding annular
rings 34 through 44 comprise the active optical area 46
of the lens, which is surrounded by a peripheral
25 (nonoptical) area 48 which is beveled at its outer
circumference at 50 to an outer circumferential edge 52.

The area of the intermediate power portion
preferably should not exceed 25% of the total area of
the full optic zone. It should be noted that the
30 intermediate power is distinct and different from the

1 intermediate peripheral curve and is preferably a
sphere.

By varying the widths of the individual
annular rings, a power profile can be created which
5 generates different ratios of distance optical power to
near and intermediate optical powers with increasing
distance from the center of the lens.

A person's pupil size is a function which is
dependent upon light intensity, and is an important
10 parameter in the design of ophthalmic lenses,
particularly contact lenses and intraocular lenses.

Reliable data was obtained from people in four
different age groups. Those less than 20 years of age,
those between 20 and 40 years of age, those between 40
15 and 60 years of age, and those over 60 years of age.
These pupil measurements were made on test subjects at
three different luminance levels, 250, 50 and 2.5
candelas per square meter (cd/m^2).

The 250 cd/m^2 level corresponds to extremely
20 bright illumination typically outdoors in bright
sunlight. The 50 cd/m^2 is a mixed level which is found
in both indoors and outdoors. Finally, the 2.5 cd/m^2
level is most typically found outdoors at night, usually
in an uneven illumination situation such as night
25 driving.

The results of these studies are given in the
following Table I, which includes in addition to the
average pupil diameter at three different illumination
levels, the standard deviation in the diameter and the
30 range associated therewith.

TABLE I
HORIZONTAL PUPIL SIZE

LESS THAN 20 YEARS OF AGE

Illumination (candelas/m ²)	Average Pupil Diameter(mm)	Standard Deviation (1σ)
2.5	6.5962	0.9450
50	4.3499	0.5504
250	3.4414	0.3159

20 to 40 YEARS OF AGE

Illumination (candelas/m ²)	Average Pupil Diameter(mm)	Standard Deviation (1σ)
2.5	4.486	0.8259
50	4.843	0.6342
250	5.040	0.4217

40 to 60 YEARS OF AGE

Illumination (candelas/m ²)	Average Pupil Diameter(mm)	Standard Deviation (1σ)
2.5	4.481	0.9787
50	3.6512	0.5692
250	3.0368	0.4304

GREATER THAN 60 YEARS OF AGE

Illumination (candelas/m ²)	Average Pupil Diameter(mm)	Standard Deviation (1σ)
2.5	4.7724	0.6675
50	3.4501	0.5106
250	2.3260	0.3435

1 Taken in combination with this data are the
determinations that have been made regarding real world
human activity typically encountered under different
illumination levels. At very high illumination levels,
5 such as that represented by 250 cd/m^2 , human activity is
typically taking place outdoors in bright sunlight and
requires distant vision tasks.

At a 50 cd/m^2 illumination level, activity
usually occurs both indoors and out, and typical human
10 activity is represented by both near and far visual
tasks.

Finally, at low illumination levels
represented by the 2.5 cd/m^2 , the activity that takes
place is typically outdoors at night and usually
15 involves distant vision tasks, such as driving an
automobile.

The corrective powers as a function of the
distance from the center of the lens must be a function
of the patient's specifically measured pupil diameter at
20 varying illumination levels, or it can be readily
determined from the above information based upon the age
of the patient.

Moreover, ocular in vivo image quality
measurement devices can be used to optimize the ocular
25 image quality in the concentric annular ring designs to
produce even more improved designs. This is
accomplished by using an in vivo image quality
measurement device, such as an aberroscope or MTF point
spread measuring device, to measure and decrease the sum
30 of the aberrations of the combination of the lens and
the eye system.

1 Obviously, many different embodiments of the
present invention are possible, with alterations of the
number of annular rings, the widths and arrangement of
the annular rings, and the optical powers assigned to
5 each of the annular rings.

 While several embodiments and variations of
the present invention for multifocal lens designs with
intermediate powers are described in detail herein, it
should be apparent that the disclosure and teachings of
10 the present invention will suggest many alternative
designs to those skilled in the art.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A multifocus, concentric annular ring lens comprising:
 - a. said lens having a front surface and an opposite back surface, wherein one of the front and back surfaces defines a central area comprising a circular disc having a spherical surface corresponding to a basic prescription Rx spherical distance optical power;
 - b. a plurality of annular rings surrounding the central area and having alternating spherical near optical powers and spherical distance optical powers; and
 - c. at least one intermediate optical power annular ring, located in the outer region of the lens optic zone, having an intermediate optical power, intermediate to the distance optical power and the near optical power, to provide visual acuity at intermediate distances.
2. A multifocus, concentric annular ring lens as claimed in claim 1, wherein the intermediate optical power annular ring is the second annular ring from the outer edge of the lens optic zone.
3. A multifocus, concentric annular ring lens as claimed in claim 1, wherein the intermediate optical power annular ring is the outermost annular ring which defines the outer circumference of the lens optic zone.
4. A multifocus, concentric annular ring lens as claimed in claim 1, wherein the intermediate optical power annular ring is an annular ring in the outer radial portion of the optic zone of the lens.

1 5. A multifocus, concentric annular ring lens
as claimed in claim 1, wherein the intermediate optical
power annular ring consists of the entire outer radial
portion of the optic zone of the lens.

5 6. A multifocus, concentric annular ring lens
as claimed in claim 1, wherein the intermediate optical
power annular ring is an annular ring in the middle
radial portion of the optic zone of the lens.

10 7. A multifocus, concentric annular ring lens
as claimed in claim 6, wherein the intermediate optical
power annular ring is near the outer edge of the middle
radial portion of the optic zone of the lens.

15 8. A multifocus, concentric annular ring lens
as claimed in claim 1, wherein the lens comprises a
contact lens to be worn on the cornea of the eye.

20 9. A multifocus, concentric annular ring lens
as claimed in claim 8, wherein the contact lens
comprises a soft hydrogel contact lens.

25 10. A multifocus, concentric annular ring
lens as claimed in claim 1, wherein the lens comprises
an intraocular lens.

30 11. A multifocus, concentric annular ring
lens as claimed in claim 1, wherein the widths of
individual annular rings are different to generate a
power profile which varies to generate different ratios
of distance optical power to intermediate and near
optical power.

35 12. A multifocus, concentric annular ring
lens as claimed in claim 1, wherein the central area and
the plurality of annular rings are formed on the rear

surface of the lens to minimize flare and glare problems.

13. A multifocus, concentric annular ring lens substantially as hereinbefore described with reference to Figure 1 or Figure 2 of the accompanying drawings.

14. The steps, features or integers disclosed in the accompanying specification or drawings individually or in any combination.

DATED: 3 May 1996

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ABSTRACT

A multifocus, concentric annular ring lens (10) wherein one of the front and back surfaces of the lens (10) defines a central area (12) comprising a circular disc having a spherical surface corresponding to a basic prescription Rx spherical distance optical power. A plurality of annular rings (14,16,18,20) surround the central area (12) and have alternating spherical near and distance optical powers, and at least one intermediate optical power annular ring (22). The immediate optical power annular ring (22) is located in the middle or outer region of the lens (10) optic zone, and its optical power is intermediate to the distance and near optical powers, to provide visual acuity at intermediate distances. The intermediate optical power annular ring (22) can be placed anywhere in the middle or outer region (26) of the lens optic zone, and can be the second annular ring from the outer edge of the lens optic zone, or can be the outermost annular ring which defines the outer circumference of the lens optic zone. The lens (10) can be a contact lens to be worn on the cornea of the eye, such as a soft hydrogel contact lens, or can be an intraocular lens.

11



F.g. 1



Fig. 2

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